**AMAZONIAN FLUVIAL ACTIVITY ON MARS: COMBINATION OF VOLCANO-TECTONIC ENVIRONMENT AND POSSIBLE SUBGLACIAL DRAINAGE IN THE GENERATION OF FLOW IN DURIUS VALLES.** N. A. Cabrol, SETI Institute/NASA Ames Research Center, Space Science Division, MS 245-3. Moffett Field CA 94035-1000, USA (ncabrol@mail.arc.nasa.gov).

**Introduction:** The Durius Valles system located in the Aeolis Southeast region of Mars covers and area comprised between 15 to 22°S and 185 to 190°W. It is bordered eastward by Ma'adim Vallis and westward by Al'Qahira Vallis but displays a separate drainage system significantly more mature than the two larger channels. It represents one of the most dense and varied hydrographic system on Mars, showing an abundant and recent diversity of hydrologic styles and lacustrine types. From the Viking imagery at 68m/pxl resolution in average and the 1:500K-scale photomosaic maps I-2257 and I-2260, we propose the reconstruction of the fluvio-lacustrine history of the Durius Valles system. Using morphological and morphometrical evidence, we suggest that possibly both volcano-tectonic activity and subglacial drainage may have played a role in the generation of flow in Durius Valles as recently as during the Amazonian.

**Geologic Setting:** The first reference to the network, then unnamed, as potentially fluvial in origin was made in the 1-5M-scale geological map of the Aeolis Quadrangle [1]. Durius has been mentioned later in works focusing on Ma'adim Vallis and Gusev crater and on the origin of the Aeolis fluvial valleys [2-7]. However, no study surveyed the Durius hydrographic system itself entirely, Kuzmin et al., [7] addressing the downstream part only in their mapping. Our study proposes a global survey of the drainage system of Durius Valles in its morphologic, hydrogeologic, and stratigraphic context and envisions the possible processes of generation of flow.

Durius Valles system covers an area of about 126,000 $km^2$, crossing geologic units diverse in ages and origins:

1- Highlands Material- Ancient cratered terrain probably consisting of interbedded and brecciated impact ejecta blankets of the large craters [1,7] observed in the Durius Valles drainage area are mostly located south of 22°S Lat. and locally in limited units to the north. The largest impact craters are 55 km in diameter and their rims are often embedded by the material of surrounding younger plains. Large volcanic constructs, small mountains and hilly material are included in the Highland Material. However, several volcanoes, such as Zephyra patera and features identified as possible magmatic extrusion seems to be superimposed on younger material and are more recent.

2- Plain Material- Plain deposits occupy a large part of the area. They are less densely cratered than the Highland Material and have varied origins. *Smooth plains:* almost featureless, looking smooth at 68m/pxl resolution. Few impact craters are superimposed and are commonly ≤3km in diameter. This type of plain is typically observed at 20.2°S/188.5°W and in impact craters flooded by fluvial valley networks. A fluvio-lacustrine hypothesis is the most likely to explain their origin. An ancient delta [7] is superimposed on one of these plains at 16.5°S/189°W. *Wrinkle-ridge plains:* they are typically observed south of the Zephyra patera volcanic complex (21.5°S/186.5°W) and are likely to be composed of lava deposits. They show lobate front flows and wrinkle-ridges. At the foot of Zephyra patera, some of the lobate flows show almost no impact cratering (always below 500m in diameter). Although the area covered by this particular flow is limited and does not enable a precise assessment of its age, it appears recent. *Ridged plains:* a different type of ridged plain is observed in basins at the outlet of fluvial valley networks and is composed of material deposited by fluvial valley networks. A typical example is located at 18.3°S/189.4°W. In a previous work, the origin of similar ridged plains has been proposed to be the result of a differential velocity of deposition in aqueous sediments [8]. *Scoured plains*: they consist of more rugged material of brighter albedo displaying rectilinear large and deep scours (typically 18.5°S/187.3°W). The scours are parallel to the channels direction and occur on each banks of the channel systems. The same type of material is observed over the entire Durius Valles drainage area, although the scours are limited to the upstream part of it, or observed only locally in the downstream region. The same type of material and groove-marking is observed in Ma'adim Vallis and has been associated in previous works with a subglacial intravalley lake [4,5,6,8]. *Hummocky plains*: material accumulated at the mouth of Durius Valles centered at 15°S/188°W consisting both of smooth, flat and darker albedo areas and region of conical mounds and hillocks that can be rounded or flat-topped generally associated with brighter albedo material. The material is progressively more dissected by large and deep fracture systems to the North to become a region of chaotic terrain where fractured knobs, hills, mounds and cones dominate. Paleochannel segments are still observed at the surface of fractured blocks and are perched compared to the more recent deposits of Durius Valles.

3- Volcanic Constructs and Materials- Several volcanic constructs dominate the area. The largest is Zephyra patera, defined as a possible composite cone early in Viking imagery survey [9]. Its profile resembles a strato-volcano [7] about 3000m high, 35km in diameter, with a caldera of 8km. Zephyra is the highest structure of a local field of smaller volcanoes including well-preserved cones several hundred of meters high, possible magmatic extrusions seen as small rounded peaks at the foot of Zephyra Patera. Southwest to Zephyra Patera, a high, partially collapsed massif might be the relict of another volcanic construct of 25-km long, 20-km large, and about 1000m high in its present state. Other structures resembling volcanoes are located west of Zephyra patera, making a total of 14 possible volcanic edifices in the region, all mostly located in the headwater region of the Durius Valles system (main channel and tributary systems). Similar massifs and possible volcanic edifices are observed east and west of Ma'adim Vallis and seem to be aligned with those of the Durius Valles region in a northeast-southwest direction. Lobate front and ridged deposits north of Zephyra patera are likely to be lava deposits

4- Structure - The headwater region of the Durius

Valles is characterized by a series of east-west trending faults that intersect most of the volcanic constructs and some localized small drainage systems located on their flanks. The fault system appears to be relatively recent, cutting both ancient cratered terrain dating from the Noachian and intercrater plains which display a much less dense impact crater population. Systems of fractures oriented northwest-southeast seem to control part of Durius Valles direction.

5- Hydrographic System- The Durius Valles system consists of about 6500 km of channel length distributed in one main fluvial network supplied by a dense tributary system and a series of small fluvial networks located to the west that debouch in the same sedimentary basin. Relicts of older and small systems are observed up to 13°S. They are located higher on eroded blocks in the plateau with respect to the most recent Durius Valles system and may constitute the legacy of an older fluvial activity. Almost all recognized fluvial styles on Mars are observed in the drainage area. *Fluvial valley networks:* networks of meandering valleys are cutting through rugged and intermediate cratered terrain. Parts of the networks are often subdued by more recent deposits that can be volcanic in origin or fluvio-lacustrine. More recent fluvial valley networks converge into impact craters or depressions and form aqueous sedimentary deposits that show rare impact cratering. Valley networks are generally elongated, with narrow arched-headwaters, all located in regions of brighter albedo, hummocky and grooved material. *Outflow channels:* the west branch of Durius Valles is supplied by an outflow channel that originates at 20.5°S and 188°W. The rupture of a crater rim released water from a lake contained in a 40-km diameter impact crater. The record of this event is seen as overflow channels cutting the crater rim. The flow rushed downstream into another crater before overflowing the plateau and the intercrater plains. The flow was divided by a ridge north-south oriented. The main channel and tributary flows originating from this outflow episode join at 18°S and 187.6°W. The other main tributary of Durius Valles located east of the main channel may have been supplied by collecting the water from the floodplain of Ma'adim Vallis [ 2-8, 10-11]. *Hydrothermal springs:* the contribution of hydrothermal processes can be, and has been [2-8, 10-11] advocated for the generation of flow in the Aeolis region. The demonstration of its role in the formation of the Durius Valles might be more favorable than for Ma'adim Vallis because of the concentration in the relatively small area of many volcanoes, fault systems and fluvial valleys. In addition, small drainage systems are observed on the flank of Zephyra patera, which morphology and morphometry correspond to the description made in previous works of potential channels generated by hydrothermal processes [12,13].

6- Lacustrine Activity - Two main types of ponding areas are identified in the drainage area: *impact crater paleolakes* formed by channels inflowing crater basins, and *aqueous sedimentary basins* formed by channels converging toward topographic lows, such as depressions. Considering the density of the Durius hydrographic network, it is probable that a significant number of smaller diameter craters filled by channels are being missed at current resolution. The area of the Durius Valles region covered by Amazonian aqueous sediment deposits is about 33,500 $km^2$, representing 20% of the drainage area that was covered by lakes and alluvial plains in the most recent geological period of Mars.

**Generation of Flow: Plausible Interaction between Volcanism and Ice:** The assumption that the volcanic activity played a role in the generation of flow in the Durius Valles is supported by the vicinity of volcanoes, faults and channel headwater systems. Headwaters are concentrated near the largest volcanic edifices, never further than 50 km away, more often in the 10-20 km distance range for the channels visible at current resolution. Some of the smallest networks are on the flanks of the volcanoes themselves. In addition, the headwater region is characterized by rugged and grooved material. The resulting morphologies in Durius Valles can be compared to terrestrial subglacial flow areas in Arctic regions. When not sedimentary in origin, scour-marks on Earth are explained by the movement of a glacier or of an ice-sheet. However, glaciers and ice-sheets need to be supplied by snow falls to advance. This precipitation mechanisms is unlikely to have happened on Mars during the Amazonian according to what we currently know of the martian atmosphere. If the scours are ice-related, the progressive freezing of outflowing water and formation of floating ice was a more likely process during the Amazonian. We then propose that the last episode of flow in Durius Valles may have been triggered by volcanism-ground ice interaction. Then, a significant part of the released water has been contained in a large impact crater which rim broke under water pressure and outflowed the northern region over 300 km. The released water may have been progressively freezing, leaving glacier-like scours in the Plateau. Some of the fluvial valleys located east of the main channel may originate from glacial spillways.

**References:** [1] Scott et al., 1978. *USGS* 1:5M Geol. Map I-1111; [2] Brackenridge, G. R. 1990. *JGR* 95; [3] Landheim, R. 1995. *Master Thesis*, ASU; [4] Cabrol et al., 1996. *Icarus* 123; [5] Cabrol et al., 1998. *Icarus* 132; [6] Cabrol et al., 1998. *Icarus* 133; [7] Kuzmin et al., 1998. *USGS* 1:500K Geol. Map *in press*; [8] *USGS* 1:2M Topog. Map, I-2119 (MC-23SE), [8] Grin E. A., and N. A. Cabrol 1997. *Icarus* 130; [9] Greeley, R. and P. D. Spudis 1978. *Geophys. Res. Let*. [10] Cabrol, N. A. et al., 1994. *LPSC 26th*; [11] Landheim, R. et al., 1994. *LPSC 26th*; [12] Gulick, V. C., and V. R. Baker 1990. *JGR* 95; [13] Gulick, V. C. 1998. *JGR* 103-E8.

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